NORTHERN ARIZONA BAT ROOST INVENTORY

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ABSTRACT

Bats represent a unique and poorly understood component of the faunal composition of Arizona.

Of the 28 species known to occur in Arizona, as many as 20 species are found on the Arizona Strip. Current knowledge, or lack thereof, accounts for sensitive status accorded to 13 species formerly recognized by the U.S. Fish and Wildlife Service as candidates for listing. Public land management agencies have a heightened awareness of bats as an important biological resource and an indicator of ecosystem health. These animals are being subjected to increasing roost site destruction and habitat degradation. Roosts, particularly for maternity and hibernation use, constitute a critical resource for promotion of healthy populations. Baseline information on distribution and habitat requirements of most species is not sufficient to prepare realistic threat assessments. The Bureau of Land Management (BLM) and the Arizona Game and Fish Department (AGFD) have identified a need to locate and protect bat roosts on the Arizona Strip.

Bats were captured, identified, and recorded at numerous sites across the Arizona Strip. Mist netting was conducted over open water sources such as stock tanks, springs, water troughs, wildlife catchments, creeks and rivers. Caves and mines suspected as bat roosting sites were inventoried to determine species present and level of use.

During the 1996 and 1997 field seasons a total of 1175 bats of 17 different species were captured (Figure 1). *Myotis volans*, *Pipistrellus hesperus*, and *M. thysanodes* were the most abundant species, comprising 26.6%, 19.6%, and 12.1% respectively of the total. Notable captures include 46 *Corynorhinus townsendii*, 18 *Euderma maculatum*, 12 *Idionycteris phyllotis*, 5 *Nyctinomops macrotis*, and 3 *Eumops perotis*. Other sensitive bat species captured include *Myotis ciliolabrum*, *M. yumanensis*, and *M. evotis*. A total of 167.7 hours of capture effort were expended during the 1996 and 1997 field seasons, for a capture success of over 7.0 bats / hour. Over 405 net hours of effort were expended during a total of 59 nights. A total of 36 net nights (61.0 percent) of capture effort was conducted in ponderosa pine habitat, 13 (22.0 percent) in pinyon juniper, and 10 (17.0 percent) in desert scrub and other low elevation habitats. Capture success was highest in pinyon-juniper habitat (8.0 bats / hour). Over 500 bats were captured over stock tanks in ponderosa pine habitats (Table 6). Capture success was highest at stock ponds in pinyon-juniper (8.7 bats / hour) and ponderosa pine (8.0 bats / hour) habitat. Of the ten sensitive species captured, two showed sex ratios divergent from the expected 1:1, including *Euderma maculatum* and *Myotis ciliolabrum.*

Twenty bats were fitted with radio transmitters during the 1997 field season including six *Euderma maculatum*, three *Corynorhinus townsendii*, three *Idionycteris phyllotis*, two *Nyctinomops macrotis*, two *Eumops perotis*, two *Myotis volans*, and two *M. thysanodes*. Of the nine females tagged, five were lactating, one was pregnant, and three were non-reproductive. Eleven males were tagged, four reproductively active and seven were non-reproductive.

Based on a combination of radio-telemetry data and cave and mine inventories, more than 40 roosts were located. The majority of these were found in caves and mines. At least 13 roost sites were located in abandoned mines and 22 were located in cracks, crevices, or small caves. All six *Euderma maculatum* roosts were located in steep rocky cliffs less than 9 mi (15 km) from the two locations where they were captured. *Euderma* roosts (n=4) were located in cracks, crevices, or holes in the upper one third of vertical cliff faces at least 75 ft (23 m) tall. Several species were detected using the lava fields in the Mt. Trumbull area, including *Myotis thysanodes* and *Corynorhinus townsendii*. Seven roosts were identified in trees or snags from six radio tagged bats. Of these, three were day roosts for *Myotis volans* in ponderosa pine in the Mt. Trumbull area. Two of the day roosts were located in ponderosa pine snags while one was found in a live tree. Two of the roosts located were used by the same radio tagged *Myotis volans*, indicating roost switching was occurring. Two of the roosts located were trees used by bats immediately following tagging. Roost trees or snags used by *Myotis volans* in the Mt. Trumbull area shared several characteristics including a dbh measurement $\geq$ 28 inches, height $\geq$ 85 feet, elevation $\geq$ 6850 feet, presence of large fissures or exfoliating bark, and distance to water $\leq$ 1.5 miles. Other roost tree characteristics, such as percent slope, position on slope, aspect, and distance to grazing, treatment areas, or foraging sites show a high degree of variability.

INTRODUCTION

Of the 44 species of bats known to occur in North America, 28 are known or suspected to occur in Arizona (Hoffmeister, 1986). This includes 20 species found north and west of the Colorado River in the portion of the State known as the Arizona Strip (Table 1). The Arizona Strip represents a relatively small geographic region that contains most of the range of elevations and many of the habitat types found throughout the State. As such, it shares most of the bat species known to occur in the contiguous states.

Current knowledge, or lack thereof, accounts for sensitive status accorded to the California leaf-nosed bat, *Macrotus californicus*; spotted bat, *Euderma maculatum*; Allen's lappet-browed bat, *Idionycteris phyllotis*; desert red bat, *Lasiurus blossevillii*; small-footed myotis, *Myotis ciliolabrum*; long-eared myotis, *Myotis evotis*; fringed myotis, *Myotis thysanodes*; cave myotis, *Myotis velifer*; long-legged myotis, *Myotis volans*; Yuma myotis, *Myotis yumanensis*; Townsend's big-eared bat, *Corynorhinus townsendii*; greater western mastiff-bat, *Eumops perotis*; and big free-tailed bat, *Nyctinomops macrotis*. These thirteen species were formerly recognized by the U.S. Fish and Wildlife Service as candidates for federal listing (USFWS, 1994). All are now recognized as BLM sensitive species in Arizona (BLM, 1998). The Arizona Game and Fish Department recognizes three of the bat species found on the Strip as being of special concern (AGFD, 1997). All of these species are known or are expected to occur on the Arizona Strip, though the occurrence of *M. velifer* is questionable.

Public land management agencies have a heightened awareness of bats as an important biological resource and an indicator of ecosystem health. These animals are being subjected to increasing roost site destruction and habitat degradation. At present, baseline information on distribution and habitat requirements of most species is not sufficient to prepare a realistic threat assessment. Even in areas where adequate inventories have been conducted, virtually no information exists about roost site selection. Roosts, particularly for maternity and hibernation use, constitute a critical resource for promotion of healthy populations.

Bats use a variety of habitat types for roosting and foraging. Roost sites used by bats include caves, mines, rock crevices, trees, lava tubes, and man-made structures such as barns and eaves of buildings. Where data is available, some species appear to exhibit preferences for specific roost types, while others are generalists and may use a variety of different types.

Traditional methods for studying bats involved capturing large numbers at roosts in caves or mines (Tidemann and Woodside, 1978). These roosts were typically characterized by identifying the bat species found there and the size of the resident population. With the advent of mist nets and harp traps, it became possible to capture bats away from roost sites, usually over open water or along foraging flyways. Locating tree or cliff face roosts of bats captured at water sources requires use of light tags or radio telemetry. This equipment is typically costly and requires a substantial time and labor commitment to use effectively. Only within the last few years have radio transmitters been commercially constructed that are both light enough and inexpensive enough to conduct radio telemetry studies with bats. To date, few such studies have been conducted in Northern Arizona, and these have been limited to only a limited number of species.

Table 1. Bat Species Known or Suspected to Occur on the Arizona Strip

Scientific Name	Common Name	Status	
		BLM	AGFD
Macrotis californicus	California Leaf-nosed Bat	S	S
Eumops perotis	Greater Western Mastiff Bat	S	S
Nyctinomops macrotis	Big Free-tailed Bat	S	
Tadarida brasiliensis	Mexican Free-tailed Bat		
Antrozous pallidus	Pallid Bat		
Corynorhinus townsendii	Townsend's Big-eared Bat	S	S
Euderma maculatum	Spotted Bat	S	
Eptesicus fuscus	Big Brown Bat		
Idionycteris phyllotis	Allen's Lappet-browed Bat	S	
Lasionycteris noctivagans	Silver-haired Bat		
Lasiurus cinereus	Hoary Bat		
Lasiurus blossevillii	Desert Red Bat	S	
Pipistrellus hesperus	Western Pipistrelle		
Myotis californicus	California Myotis		
Myotis ciliolabrum	Small-footed Myotis	S	
Myotis evotis	Long-eared Myotis	S	
Myotis thysanodes	Fringed Myotis	S	
*Myotis velifer**	Cave Myotis	S	

Myotis volans	Long-legged Myotis	S
Myotis yumanensis	Yuma Myotis	S

* Questionable capture record

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PROJECT OBJECTIVES

Objectives of the Northern Arizona Bat Roost Inventory were to:

1. Identify and map key use areas for bats on BLM-administered public lands on the Arizona Strip. Key use areas included roosts in trees, snags, caves, mines, cliff faces, bridges, and culverts; watering areas at springs, stock tanks, and catchments; and foraging areas. Priority was given to bat species of concern (Table 1) as listed on the Arizona Game and Fish Department's Wildlife of Special Concern in Arizona (AGFD, 1997) and the Arizona BLM Sensitive Species List (BLM, 1998).

2. Within a fifteen mile radius of the Mt. Trumbull Ecosystem Restoration project:
   A. Locate bat roosts in all habitat types.
   B. Identify characteristics of trees / snags used as bat roosts. Map the availability of suitable roost trees / snags.
   C. Develop a model to predict which trees / snags are most likely to be occupied roosting sites during the active season. Apply the model to control areas, pre-treatment, and treated areas within the context of the Ecosystem Restoration Project.
   D. Evaluate the impacts of ecosystem restoration treatments on bat populations and

the availability of roost habitat.

E. Where possible, document roost-switching and/or evidence of roost site fidelity by bats.

F. Evaluate the level of bat use of wildlife water developments in the area.

STUDY AREA

The study area included the region north and west of the Colorado River in Arizona (Figure 1). The area known as the Arizona Strip encompasses about 3.2 million acres. Potential bat roosting sites were evaluated on public lands administered by the Bureau of Land Management, an area of about 2.8 million acres. Occasional trips were made to neighboring regions on the Strip including those administered by Grand Canyon National Park, Lake Mead National Recreation Area and the North Kaibab Ranger District of the Kaibab National Forest.

Priority was given to ponderosa pine habitat in the vicinity of Mt. Trumbull (T.35 N., R.08 W. Gila and Salt River Meridian), the Parashant Field Station (T.32 N., R.12 W. G&SRM), and Black Rock Mountain (T.39 N., R.14 W. G&SRM). Other areas of interest included isolated watering areas within a few miles of steep cliff habitat, such as Ft. Pierce Wash (T.42 N., R.11 W. G&SRM), where spotted bats have historically been common; active or abandoned mines, such as the Grand Gulch area (T.34 N., R.14 W. G&SRM); and caves with evidence of bat use.

Sampling locations on the Arizona Strip were limited to areas containing target species of interest based on past collecting localities. These species include, but are not limited to, California leaf-nosed bat, *Macrotus californicus*; spotted bat, *Euderma maculatum*; Allen's big-eared bat, *Idionycteris phyllotis*; silver-haired bat, *Lasionycteris noctivagans*; red bat, *Lasiurus blossevillii*; small-footed myotis, *Myotis ciliolabrum*; long-eared myotis, *Myotis evotis*; fringed myotis, *Myotis thysanodes*; *Myotis volans*; Yuma myotis, *Myotis yumanensis*; Townsend's big-eared bat, *Corynorhinus townsendii pallescens*; greater western mastiff-bat, *Eumops perotis*; and big free-tailed bat, *Nyctinomops macrotis*. Site elevations ranged from less than 1,800 feet to over 7,000 feet above mean sea level. Criteria for selecting the sites included availability of water, evidence of bat activity, and diversity in elevation.

In 1994, the Arizona State Mine Inspector's Office initiated an abandoned mine inventory on Arizona Strip. This inventory was approximately 40 percent complete by the conclusion of this Bat Roost study. An interim report provided a list of mine shafts and adits located in the western half of the Arizona Strip, noting sites where evidence of bat use was observed. Evidence of bat use included guano, piles of insect parts, odor, staining, or visual observations. Mine workings with evidence of bat use were evaluated for their potential as bat roosts.

The BLM maintains a list of caves on the Arizona Strip with notations about bat use. This list was reviewed and sites with evidence of or potential for bat activity were visited.

METHODS

Potential roost sites were examined to determine the numbers and species of bats present. The primary focus was to locate significant day roosts and/or maternity roosts used by sensitive bat species. Night roosts and transient roosts were also evaluated, as well as the potential sites to be used as a hibernacula.

Bats were captured for identification year round using mist nets, harp traps, and trip lines. Light tags were affixed to target bat species (Table 2) in order to locate foraging areas and/or night roosts. Radio telemetry tags were attached to target bat species to locate day and/or night roosts. Specific measurements were taken at trees and snags suspected to be bat roosts to evaluate whether roost selection is random or bat species exhibit preferences for sites with particular characteristics. Exit counts, acoustic surveys, and various capture methods were used to determine bat species composition and relative abundance at cave and mine roosts. Bat echolocation calls were collected using an ultrasonic bat detector for the purpose of developing a catalog of verified bat vocal signatures specific to northwestern Arizona. Bat guano was occasionally collected from captured bats and at roost sites for future prey preference analysis.

The use of any particular capture method was determined by the nature of the capture site (i.e. cave, mine, water tank, pond, creek, etc.), the physical size of capture area, characteristics of the surrounding landscape (i.e. presence of tall or overhanging vegetation), and weather conditions.

Mist nets were used to capture bats at open water sources, including small creeks, rivers, wildlife catchments, springs, seeps, troughs, and stock tanks. All mist nets used were 32 mm (1½") mesh, 50 denier, 2-ply nylon. Dimensions of the four sizes of mist nets used were: 2.1 x 5.5 m (7' x 18'), 2.1 x 9.1 m (7' x 30'), 2.1 x 12.8 m (7' x 42'), and 3.0 x 18.3 m (10' x 60'). Nets were typically set low over open water, perpendicular to suspected flyways and the wind, to capture bats as they came in to drink. Vegetation, rocky outcrops, and other natural features were utilized as cover for net sets to impede detection by bats whenever possible. Variations in methodology were occasionally necessary for unique situations. A floating platform was used to support the net over large ponds (Herder, 1998 in press). A boat was used to remove bats from the net. Telescoping and locking pole systems were used to erect a canopy net set (Gardner *et al.*, 1989) where several nets of the same length were stacked one above the other to capture high flying species. Nets were lowered on a pulley system to remove bats from the higher panels.

Whenever possible, bat capture equipment was assembled and set up at least 30 minutes prior to sunset. Nets typically were opened between 19:45 hours and 20:00 hours MST and were left open for a minimum of two hours. Nets were monitored every few minutes for bats, though in most instances field crews were asked to remain quiet and sit at some distance from the nets to avoid influencing bat activity. Netting operations were discontinued when a sufficient number of target bats were captured for radio telemetry work. This was typically no more than four individuals per night. Capture operations were also discontinued when it rained, when winds exceeded 10 mph, and when at least one hour had passed where no bats were captured or detected.
Mist net capture effort was evaluated in terms of the number of sites netted, the number of net

nights (total number nights of capture at all sites), and the number of net hours of effort (number hours of capture times the number of nets). Various parameters for evaluating mist net capture success were used. While none could account for all sampling biases, the most effective measure proved to be the number of bats per hour per 10 m^2 net area.

In addition to mist nets, various alternative capture methods were employed including use of harp traps (Constantine, 1958; Tuttle, 1974; Tideman and Woodside, 1978), and trip lines. Double frame harp traps measuring 1.2 m (4') wide by and adjustable to 2.7 m (9') tall strung with 8 pound test monofilament fishing line were used to capture bats at mine and cave entrances. The traps consist of a double frame with fishing line hung vertically between the frames. A bag suspended below the frames caught captured bats as they fell. Bats typically banked vertically to pass through the first set of lines, only to run into the second set. Where roosts were known or suspected to be more than ten animals, escape openings were left around the edges of the trap to allow some bats to avoid capture.

Table 2. Sensitive Bat Species on the Arizona Strip and Priority For Radio Tag Attachment

Scientific Name	Common Name	Probable Roosting Habitat
Idionycteris phyllotis	Allen's Lappet-browed Bat	Forest
Lasiurus blossevillii	Western Red Bat	Forest, Riparian
Euderma maculatum	Spotted Bat	Cliffs, Canyons
Corynorhinus townsendii	Townsend's Big-eared Bat	Caves, Mines, Lava Flows, Forest
Myotis thysanodes	Fringed Myotis	Caves, Mines, Lava Flows, Forest, Cliffs
Myotis volans	Long-legged Myotis	Forest
Myotis yumanensis	Yuma Myotis	Caves, Mines, Forest
Myotis evotis	Long-eared Myotis	Forest, Rocks, Cliffs
Eumops perotis	Greater Western Mastiff Bat	Cliffs, Canyons
Nyctinomops macrotis	Big Free-tailed Bat	Cliffs, Canyons
Eptesicus fuscus	Big Brown Bat	Forest

Trip lines were established by setting up a grid of light weight monofilament fishing line in parallel rows over a water tank, small creek, or shallow pool. The trip lines were typically set about 1 foot apart and approximately ½" to 1" above the water surface. This method was particularly effective at small or odd shaped pools of water or locations where it was not practical to set up a standard mist net. Bats attempting to drink would "trip" over the fishing line and fall into the water. Researchers would retrieve them, dry them off, and collect the necessary data.

Known or suspected roosts at mines or caves were monitored externally using exit counts, often in conjunction with acoustic survey techniques. Exit counts were conducted by a single stationary observer counting bats entering and exiting the opening. Lanterns and flashlights with red filters were used to illuminate cave and mine entrances with minimal disturbance to bats. When available, generation III PVS-7 Bravo head mounted goggles (Tactical Night Technologies, Roseville, CA, USA) with a built-in infrared light source were used. Lap counters were held in each hand, tallying exiting bats in one hand and entering bats on the other. The number entering was then subtracted from the number exiting to reduce bias from bats who exit and then re-enter the roost and account for night roosting.

When possible, acoustic surveys were conducted to determine species identity. An Anabat II ultrasonic bat detector (Titley Electronics, Ballina, NSW Australia), was interfaced with a notebook computer and used to record vocalizations of free-flying and hand-released bats coincident with capture operations and/or exit counts. The Anabat station was set up at each site in an open area so as not to interfere with bat activity. Vocalizations of free-flying bats were saved to the computer's hard drive. The file name and comments about the call sequences were recorded on data sheets.

Captured bats were placed in mesh bags or holding buckets for processing. Processing included recording the time of capture, species, gender, reproductive status, ear length, tragus length, forearm length, and weight. In the interest of time, only weight, gender, and reproductive status were recorded for commonly captured species. Most bats were marked superficially with a felt tip marking pen and released shortly after processing. The mark aided researchers in determining if the same individual was recaptured later the same evening. Species for which verified vocal signatures were needed were held until all nets were closed for recording the bats from a hand release.

A cyalume glow stick (light tag) (Chemical Light Inc., Wheeling, IL, USA) weighing approximately 0.2 g was attached to target bat species to record the vocal signature of a known species, locate a roost or foraging areas, or assist in relocating radio tagged bats of the same species. A small patch of fur was trimmed in the interscapular area (between the shoulder blades) using manicurist scissors to provide an attachment site. A small amount of Skinbond surgical glue (Smith and Nephew United, Largo, FL, USA) was placed on the attachment site and on the light tag and allowed to cure for five minutes. The anterior half of the activated tag was then laid on the attachment site. The surrounding hair was rolled into the glue to provide firm but temporary attachment. The remainder of the tag (posterior unglued end) rested on the animal's back, clearly visible. Observers were then positioned along suspected flight paths, lights and noise were kept to a minimum, and the bat was released. Observers noted the time, direction of travel, and apparent activity of the light-tagged bat.

Sensitive bat species were preselected and prioritized to carrying a radio transmitter (Table 2). A

Holohil Systems (Ottawa, Ontario, Canada) or Titley (Titley Electronics, Ballina, NSW Australia) radio transmitter weighing from 0.42 to 0.68 g was affixed interscapularly using the surgical glue Skinbond. Transmitter life varied from a maximum of 14 days (0.42 g) to a maximum of 35 days (0.68 g). Radio transmitters were selected based upon the weight and reproductive status of the bat. In general, bats were tagged only if the weight of the tag was less than five percent of the animals body weight. Lactating females were typically not tagged. The hair at the attachment site was spread and trimmed as necessary in order to allow a direct glue bond between skin and transmitter. Hair was left at the attachment site if it was determined to be desirable that the tag should fall off the animal prior to the battery expiration. The bat was held for up to 45 minutes prior to release to allow the glue to cure and dry. Observers were then positioned along suspected flight paths with radio telemetry receivers, lights and noise were kept to a minimum, and the bat was released. Observers noted the time and direction of travel of the radio-tagged bat. Tagged bats were followed as far as was possible. Once the bat was out of range of the telemetry equipment, observations concluded for the night. Extensive relocation efforts were resumed during daylight hours throughout the immediate area. Additional night time searches were conducted for selected species (Table 2) in an effort to locate foraging areas and more distant roost sites. When necessary, a fixed wing aircraft was used to expand the search area.

Capture data was tallied and analyzed by species, sex, age class, reproductive status, habitat type, and the water type at the capture location to determine if trends were apparent. A G-test was used to test the goodness of fit of sex ratios to a chi-square distribution (Sokal and Rohlf, 1995) based upon an expected sex ratio of 1:1. The number of bats / hour and bats / hour / 10 m^2 net surface area were used to evaluate effort and capture success.

Roosts located in trees or snags were characterized by collecting the following data: location (UTM coordinates), species of tree, diameter at breast height (using a dbh tape), height of tree (using a clinometer), height of roost, stage of bark exfoliation, percent slope (using a clinometer), slope aspect, elevation, position of tree on slope (based upon 1/5th length of slope), distance to open water, distance to nearest forest opening ≥ 0.5 ha, and distance to and stage of nearest restoration treatment area. In an effort to determine whether bats were selecting roost trees/snags at random or based upon specific characteristics, we chose five non-overlapping 11.3 m radius plots (0.04 ha each) as described by Rabe *et al.* (1998. In press). One was centered on the roost tree/snag while the others were located at random distances from 20 - 50 m from the roost tree/snag in the each of the four cardinal directions. Data collected within plots included basal area at the center of the plot, percent canopy closure, number of trees within each of five dbh classes, the total number of trees per acre, number of shrub species, number of individual shrubs, number of snags, number of downed logs, and evidence of recent grazing.

Following a determination that roost trees/snags had characteristics different than random trees/snags, the intent was to develop a model for identifying roost trees/snags in control, untreated, and treated areas. These roosts would then be examined for bats. The model would also be used to evaluate the impacts of the forest restoration project on bat roosts and predict whether pre-settlement forest conditions would provide more or fewer roost sites.

All project personnel were trained in bat identification and handling, capture methods, acoustic surveys, cave and mine safety considerations, and minimizing roost disturbance. All personnel were also required to have rabies pre-exposure vaccinations prior to handling bats.

RESULTS

Capture Effort and Results

During the 1996 and 1997 field seasons a total of 1175 bats of 17 different species were captured (Figure 2). *Myotis volans*, *Pipistrellus hesperus*, and *M. thysanodes* were the most abundant species, comprising 26.6%, 19.6%, and 12.1% respectively of the total number of bats captured. Notable captures include 46 *Corynorhinus townsendii*, 18 *Euderma maculatum*, 12 *Idionycteris phyllotis*, 5 *Nyctinomops macrotis*, and 3 *Eumops perotis*. Other sensitive bat species captured during the two field seasons include *Myotis ciliolabrum*, *Myotis yumanensis*, and *Myotis evotis*. Individuals of ten of the thirteen sensitive bat species were captured during the study. No individuals of *Lasiurus blossevillii*, *Macrotus californicus*, or *Myotis velifer* were captured during the study, though *Lasiurus blossevillii* and *Macrotus californicus* have previously been captured on the Arizona Strip.

A total of 167.7 hours of capture effort were expended during the 1996 and 1997 field seasons, for a capture success of over 7.0 bats / hour. Over 405 net hours of effort (hours of effort times the number of nets set) were expended during a total of 59 nights.

Capture Success by Habitat Type

Capture operations were conducted in three different habitat types: desert scrub - sagebrush at elevations generally below 4,500 feet, pinyon-juniper woodlands at elevations from approximately 4,500 feet to 6,000 feet, and ponderosa pine at elevations above 6,000 feet. A total of 36 net nights (61.0 percent) of capture effort was conducted in ponderosa pine habitat (Table 3). Thirteen net nights (22.0 percent) were expended in pinyon juniper habitat and ten net nights (17.0 percent) in desert scrub and other low elevation habitats. Capture success was highest in pinyon-juniper habitat (8.0 bats / hour), slightly less in ponderosa pine habitat (7.3 bats / hour), and lowest in desert scrub - sagebrush habitat (4.8 bats / hour) (Table 3). The same trend holds true when comparing capture rates over a standardized 10m^2 net area.

Table 3. Bat Capture Success and Species Diversity on the Arizona Strip by Habitat Type, 1996 and 1997 Field Season

	Elevation Range	Number Net Nights	Capture Success Bats / Hour	Capture Success Bats / Hour / 10m^2 Net	Number Species Captured
Ponderosa Pine	above 6,000 ft.	36	7.3	0.04	13
Pinyon-Juniper	4,500 ft. to 6,000 ft.	13	8.0	0.14	12

Higher elevation sites showed greater species diversity, as evidenced by the number of species captured (Table 3). More individuals were captured at higher elevation sites for nine of the ten sensitive species encountered (Table 4). *Euderma maculatum* was the only sensitive species where more individuals were captured in lower elevations habitats. Four of these species, *Idionycteris phyllotis*, *Eumops perotis*, *Nyctinomops macrotis*, and *Myotis evotis*, were only captured in ponderosa pine habitat (Table 4).

Table 4. Bat Capture Success on the Arizona Strip by Habitat Type, 1996 and 1997 Field Seasons

Scientific Name	Sensitive Status	Number Bats Captured by Habitat Type		
		Ponderosa Pine (n=36)	Pinyon-Juniper (n=13)	Desert Scrub - Sagebrush (n=10)
Myotis volans	S	247	63	2
Pipistrellus hesperus		93	70	67
Myotis thysanodes	S	135	6	1
Eptesicus fuscus		111	50	14
Antrozous pallidus		28	14	20
Corynorhinus townsendii	S	38	6	2
Tadarida brasiliensis		72	10	22
Myotis yumanensis	S	10	1	1
Idionycteris phyllotis	S	12	0	0
Myotis ciliolabrum	S	20	12	0
Euderma maculatum	S	7	0	11
Myotis californicus		7	4	1
Eumops perotis	S	3	0	0
Nyctinomops macrotis	S	5	0	0
Lasiurus cinereus		1	0	0

Lasionycteris noctivagans		1	3	0
Myotis evotis	S	1	0	0

n = number of net nights
S = Sensitive Species status

Capture Effort and Results by Water Type

Bats were captured over three different water types, stock ponds (earthen reservoirs), wildlife catchments (rectangular metal trough or drinker), and riparian waterways. Of these, capture success, measured in bats / hour, was highest and species diversity greatest at stock ponds (Table 5). Capture success and species diversity decreased at catchments and riparian areas. Capture success / 10m^2 net area was highest for riparian areas and catchments and declined sharply for stock tanks (Table 5).

Table 5. Bat Capture Success on the Arizona Strip by Water Type
1996 and 1997 Field Seasons

	Number Net Nights	Capture Success Bats / Hour	Capture Success Bats / Hour / 10m^2 Net	Number Species Captured
Stock Ponds	34	7.8	0.03	16
Catchments	18	6.1	0.14	11
Riparian	7	5.1	0.19	9

Five species were captured only over stock ponds including *Idionycteris phyllotis*, *Eumops perotis*, *Nyctinomops macrotis*, *Lasiurus cinereus*, and *Lasionycteris noctivagans*. *Myotis yumanensis* was captured almost exclusively over stock ponds. The only exception was a single individual *M. yumanensis* captured over a riparian waterway.

Bats of ten different species were captured over troughs or drinkers at wildlife catchments. The majority of individuals captured at catchments typically weighed less than 8 grams. This included species such as *Myotis volans*, *Pipistrellus hesperus*, *Myotis thysanodes*, *Corynorhinus townsendii*, *Myotis ciliolabrum*, *Myotis californicus*, and *Myotis evotis*.

Capture Effort and Results by Habitat and Water Type

Over 500 bats were captured over stock tanks in ponderosa pine habitats (Table 6). Capture success was highest at stock ponds in pinyon-juniper (8.7 bats / hour) and ponderosa pine (8.0 bats / hour) habitat. Capture success rates based upon a standardized net surface area of 10m^2 were highest for water catchments in pinyon-juniper habitat (0.75 bats / hour /10m^2 net surface).

Other notable capture success rates based upon standardized effort include riparian water sources in desert scrub - sagebrush habitat (0.19 bats / hour /10m^2 net surface), stock tanks in pinyon-juniper (0.17 bats / hour /10m^2 net surface), water catchments in ponderosa pine (0.16 bats / hour /10m^2 net surface), and stock tanks in desert scrub - sagebrush habitat (0.16 bats / hour /10m^2 net surface) (Table 6). The highest species diversity, evidenced by the number of bat species captured, occurred over stock ponds in ponderosa pine habitat (Table 6).

Table 6. Bat Capture Success by Habitat and Water Type on the Arizona Strip, 1996 and 1997 Field Seasons

	Number Net Nights	Bats Captured	Capture Success Bats / Hour (/ 10m^2 Net)	Number Species Captured
Ponderosa Pine	36	794	7.3 (0.04)	16
Stock Ponds	20	517	8.0 (0.05)	16
Catchments	16	277	6.4 (0.16)	9
Riparian	0	0	0	0
Pinyon-Juniper	13	240	8.0 (0.14)	11
Stock Ponds	11	229	8.7 (0.17)	11
Catchments	2	11	3.1 (0.75)	2
Riparian	0	0	0	0
Desert Scrub - Sagebrush	10	141	4.8 (0.09)	9
Stock Ponds	3	32	3.8 (0.16)	9
Catchments	0	0	0	0
Riparian	7	109	5.1 (0.19)	6

Capture Effort and Results by Sex, Age, and Reproductive Condition

Of the ten sensitive species captured, two showed sex ratios significantly divergent from 1:1. These were *Euderma maculatum* (14 males and 4 females; G=5.884, P<0.025) and *Myotis yumanensis* (11 males and 1 female; G=9.751, P<0.005). All four female *Euderma maculatum* were captured in ponderosa pine habitat at elevations above 6,000 feet, while all 14 males were captured at elevations below 6,000 feet, generally in desert scrub-sagebrush habitat. A skewed sex ratio was also noted in captures of *Nyctinomops macrotis* (0 males and 5 females) and *Lasionycteris noctivagans* (four males and no females), though the sample size was insufficient for tests of significance.

Among sensitive bat species, the date of capture for pre-parturition females varied from 10 June through 24 June for *Myotis volans* (n=13 bats over four net nights) (Table 7) and 17 June through 23 June for *M. thysanodes* (n=2 over two net nights) . By comparison, pre-parturition *Eptesicus fuscus* were captured from 10 June through 31 July (n=17 over three net nights).

The date of capture for lactating female *Myotis volans* varied from 17 June through 8 August (n=27 over 13 net nights) (Table 7). Lactating *M. thysanodes* were captured from 4 July through 23 July (n=40 over five net nights) and lactating *Eptesicus fuscus* were captured from 29 May through 6 August (n=18 over nine net nights).

Sub-adult *Myotis volans* first appeared after 24 June, *M. thysanodes* after 16 July (n=18 over nine net nights and n=5 over three net nights respectively). Young of the year *Eptesicus fuscus* appeared after 2 July (n=8 over three net nights) (Table 7).

Table 7. Date of Capture of Sensitive Bat Species on the Arizona Strip by Reproductive Status, 1996 and 1997 Field Seasons

Scientific Name	Sensitive Status	Number Bats Captured by Reproductive Status		
		Pre-Parturition (Pregnant)	Post Parturition (Lactating)	Volant Young (Subadults)
Myotis volans	S	6/10 - 6/24 n=13 nn=4	6/17 - 8/12 n=27 nn=13	6/24 - 8/20 n=18 nn=9
Myotis thysanodes	S	6/17 - 6/23 n=2 nn=2	7/4 - 7/23 n=40 nn=5	7/16 - 8/4 n=5 nn=3
Corynorhinus townsendii	S	No data	5/29 - 7/17 n=16 nn=6	7/2 n=1 nn=1
Idionycteris phyllotis	S	6/10 n=1 nn=1	No data	No data
Myotis ciliolabrum	S	6/17 n=1 nn=1	6/26 - 7/16 n=6 nn=4	No data
Euderma maculatum	S	No data	7/7 n=1 nn=1	No data
Eumops perotis	S	No data	7/31 n=1 nn=1	No data
Nyctinomops macrotis	S	No data	7/31 n=1 nn=1	No data
Eptesicus fuscus		6/10 - 7/31 n=17 nn=3	5/29 - 8/6 n=18 nn=9	7/2 - 7/31 n=8 nn=3

n = number of individual bats captured
nn = number of net nights capture effort

Radio Telemetry Results

No bats were radio tagged during the 1996 study as funds to purchase the tags were not available until well into the field season. Twenty bats were fitted with radio transmitters during the 1997 field season. These included six *Euderma maculatum*, three *Corynorhinus townsendii*, three *Idionycteris phyllotis*, two *Nyctinomops macrotis*, two *Eumops perotis*, two *Myotis volans*, and two *M. thysanodes* (Table 8). Radio signals were reacquired at least once during the life of the transmitter for each of the telemetered bats with the exception of one *Corynorhinus townsendii* and one *Nyctinomops macrotis*.

Nine female and eleven male bats were fitted with radio transmitters. Of the females tagged, five were lactating, one was pregnant, and three were non-reproductive. Among the males tagged, four were reproductively active, as evidenced by descended testes, and seven were non-reproductive.

Table 8. Sex, Age and Reproductive Status of Radio-Transmittered Bats on the Arizona Strip, 1997 Field Season

Date 1997	Species Tagged	Sex and Reproductive Status	Habitat at Tagging Location	Weight in grams	Roost Located
06/26	Corynorhinus townsendii	Female - L	Ponderosa pine	9.0	-
06/26	Corynorhinus townsendii	Female - L	Ponderosa pine	9.0	-
07/29	Corynorhinus townsendii	Female - NR	Ponderosa pine	9.3	Oak grove
06/03	Euderma maculatum	Male - TD	Desert scrub	16.5	Cliff face
06/03	Euderma maculatum	Male - TD	Desert scrub	16.0	Cliff face
06/23	Euderma maculatum	Male - NR	Desert scrub	14.0	Cliff face
06/23	Euderma maculatum	Male - NR	Desert scrub	14.2	Cliff face
07/07	Euderma maculatum	Male - TD	Ponderosa pine	15.0	Cliff face
07/07	Euderma maculatum	Female - L	Ponderosa pine	14.6	Cliff face
07/30	Eumops perotis	Male - NR	Ponderosa pine	44.0+	Cliff area
07/31	Eumops perotis	Female - L	Ponderosa pine	44.0+	Cliff area
06/10	Idionycteris phyllotis	Female - P	Ponderosa pine	12.0	Aspen grove
07/07	Idionycteris phyllotis	Male - NR	Ponderosa pine	9.5	-

07/31	Idionycteris phyllotis	Male - NR	Ponderosa pine	8.6	-
07/29	Myotis thysanodes	Male - TD	Ponderosa pine	7.0	-
08/05	Myotis thysanodes	Male - NR	Ponderosa pine	7.4	Rocky cliff
07/29	Myotis volans	Female - NR	Ponderosa pine	9.0	P. pine snag
08/04	Myotis volans	Male - NR	Pinyon-juniper	8.2	P. pine snag
07/31	Nyctinomops macrotis	Female - L	Ponderosa pine	26.5	-
07/31	Nyctinomops macrotis	Female - NR	Ponderosa pine	25.6	-

L = Lactating NR = Non-reproductive TD = Testes descended

The weight of each individual selected to carry a radio transmitter was determined prior to application of the tag. Seventeen of the twenty bats selected carried a transmitter that weighed less than five percent of their overall body weight. Both *Myotis thysanodes* and one *M. volans* carried transmitters that were less than ten percent of their overall body weight. *Myotis thysanodes* selected weighed between 7.0 and 7.5 grams (Table 8).

Roost Locations

Based on a combination of radio-telemetry data and cave and mine inventories, more than 40 roosts were located. The majority of these were found in caves and mines. While the study focused primarily on day roosts, some night roosts were also located. At least one cave is suspected as a maternity colony as a female *Eptesicus* was captured adjacent to the entrance with a non-volant young attached. Another cave is a suspected hibernacula, those this was not confirmed as surveys were only conducted during the warm season.

The Arizona State Mine Inspectors Office conducted external examinations at 16 shafts and 12 adits on the Arizona Strip during 1996 and 1997. This comprises approximately 45 percent of the total shafts and adits on the Arizona Strip. Internal surveys, exit counts, or acoustic and/or mist net surveys were conducted on all of these mine openings. Eight shafts and five adits were used as day roosts by one or more species (Appendix A).

At least 22 roosts sites were located in cracks, crevices, or small caves (Appendix B). Locations in narrow sandstone canyons provided extensive habitat for roosts of a variety of species. The Virgin River Gorge along Interstate Highway 15 contains virtually thousands of cracks, crevices, and small caves, many of which provide roosting habitat for bats.

All six *Euderma maculatum* roosts were located in steep rocky cliffs less than 9 mi (15 km) from the two locations where they were captured. *Euderma* roosts (n=4) were located in cracks, crevices, or holes in the upper one third of vertical cliff faces at least 75 ft (23 m) tall. One roost was located in a cave-like formation where a vertical rock slab approximately 100 ft (31 m) tall and 30 ft (9 m) wide had slumped down from the cliff face above. Inspection of the site revealed that other species were using the "cave" including several *Corynorhinus townsendii.*

Several species were detected using the lava fields in the Mt. Trumbull area, including *Myotis thysanodes* and *Corynorhinus townsendii*. Exit counts over lava flows were typically low, but indicated significant use over a broad area.

Seven general roost locations were identified in trees or snags from six radio tagged bats (Appendix C). Of these, three were day roosts for *Myotis volans* in ponderosa pine in the Mt. Trumbull area. Two of the day roosts were located in ponderosa pine snags while one was found in a live tree. Two of the roosts located were used by the same radio tagged *Myotis volans*, indicating roost switching was occurring. Two of the roosts located were found in trees used by bats immediately following tagging.

Roost trees or snags used by *Myotis volans* in the Mt. Trumbull area shared several characteristics including a dbh measurement $\geq$ 28 inches, height $\geq$ 85 feet, elevation $\geq$ 6850 feet, presence of large fissures or exfoliating bark, and distance to water $\leq$ 1.5 miles. Other roost tree characteristics, such as percent slope, position on slope, aspect, and distance to grazing, treatment areas, or foraging sites show a high degree of variability.

DISCUSSION

Capture Results

Capture operations for the study were considered very successful. Capture success was measured in terms of bats / hour and bats / hour / 10 m^2 net surface. While these measures of effort still contain a variety of sources of bias, results suggest they can be used as a means of evaluating differences in netting success between sites and on different nights.

The composition of bat species captured was generally consistent with expected, but with a few exceptions. Prior to the study, *Eumops perotis* had been acoustically detected but never captured on the Arizona Strip. However, *E. perotis* has been captured at Big Springs on the North Kaibab Ranger District, Kaibab National Forest (Melissa Siders, pers. comm.), approximately 75 mi (121 km) ENE of the capture site on the Arizona Strip. Published distribution records indicate that this species does not occur north of the Colorado River in Arizona (Hoffmeister, 1986; Cockrum et al., 1996).

The paucity of *Myotis evotis* captures was surprising, based upon the frequency of their capture on the North Kaibab (Melissa Siders, pers. comm.). Only two *M. evotis* have been captured on the Arizona Strip since capture records have been maintained, despite the presence of suitable roosting and foraging habitat.

The absence of *Myotis velifer* from capture results is not surprising as distribution records for this species indicate no occurrence north of the Colorado River (Hoffmeister, 1986). The single record of *M. velifer* from the Arizona Strip was a report of a bat captured at Jacob's Well in 1995 that escaped prior to taking any measurements. In the absence of substantiating data or photos, this identification is considered invalid.

While *Lasiurus blossevillii* and *Macrotus californicus* have previously been captured on the Arizona Strip, neither species was captured during the course of this study. *Lasiurus blossevillii* is considered a rare species throughout much of its range. It is therefor not surprising that this species was not captured. Cockrum, et. al (1996) report a historic roost of *Macrotus* in the Virgin River Gorge from a specimen taken in 1945. Effort was expended during this study to relocate this roost, but the "tunnel" referred to was not found. Construction of Interstate Highway 15 likely destroyed the roost or caused the bats to relocate.

Capture success by habitat type was also consistent with expected results, though capture efforts favored ponderosa pine habitat. This was done in order to accomplish Study Objective 2 in the Mt. Trumbull area. The number of nights of capture effort expended by habitat type indicated excellent coverage of ponderosa pine types and clumped but adequate coverage in pinyon-juniper and desert scrub habitat types. This high-grade approach to sampling lower elevation sites was due in part to focusing effort on known watering sites and potential roosts in mines and caves.

High capture success in pinyon-juniper habitat was not unexpected. The two most commonly captured species, *Myotis volans* and *Pipistrellus hesperus*, occur across a wide elevational range. *Pipistrellus* are most common at low elevations but are also common in pinyon-juniper habitat. *Myotis volans* are most abundant at higher elevations but, like *Pipistrellus,* are also common in pinyon-juniper habitat.

Ponderosa pine habitat makes up less than two percent of the Arizona Strip. In addition, the arid nature of these areas and proximity to excellent roosting habitat makes the islands of ponderosa pine ideal locations for a variety of bat species.

Capture success in bats / hour was higher for stock ponds than catchments or riparian areas. However, when evaluated over a standardized net surface area of 10 m^2, riparian areas showed the highest capture success. This was most likely due to the need to use more and larger nets to adequately cover stock ponds. Narrow riparian corridors and small rectangular catchment drinkers typically required only minimal net surface area for adequate coverage.

All five species captured only over stock ponds are among the largest bats found on the Arizona Strip. All have wings designed for long sustained flights (Barbour and Davis, 1966) and are not equipped for high maneuverability. This suggests that waters must be greater than or equal to some minimum size in order to provide adequate area for these bats to drink. In contrast, the majority of bats captured at catchments were smaller, more maneuverable species. The high level of use at these catchments typically designed for big game suggests that the spacing of artificial waters may be important to the distribution of smaller bat species.

Two of the ten sensitive species captured showed sex ratios significantly divergent from 1:1. Changes in the observed sex ratios of captured bats may vary seasonally and from site to site, particularly where sexes spatially segregate during the breeding season. However, this has not been documented for *Euderma maculatum*, nor was any documentation found to substantiate any particular sex ratio. All four female *Euderma maculatum* were captured in ponderosa pine habitat at elevations above 6,000 feet. Eleven of the fourteen male *Euderma* captured were caught in desert scrub-sagebrush habitat over a riparian waterway. Earlier work at this capture site indicates that females are rarely taken here (Poche and Baillie, 1974; Poche and Ruffner, 1975; Poche, 1975; Poche, 1981). Most records of females captured here were taken during the cold season. In contrast, all four females were captured in ponderosa pine habitat. Female *Euderma* are moderately common in ponderosa pine habitat on the North Kaibab (Rabe, et al., 1998 in press). Rabe et al., (1998 in press) reported a female they tagged on the North Kaibab traveled over 24 mi (38.5 km) between her foraging area in the ponderosa pine meadows of the Kaibab Plateau and her suspected roost in the Grand Canyon. While the number of documented occurrences of this long distance travel in *Euderma* is quite low, evidence suggests that males and females roost at low elevations and segregate to forage. Females may be traveling to higher elevation sites to forage, presumably for some high energy prey source, while males appear to stay closer to the roosting locations.

Unequal sex ratios were also observed for *Myotis ciliolabrum*, *Myotis yumanensis*, and *Nyctinomops macrotis*. It is likely that capture results were affected by netting close to a roost location where some type of sexual segregation may have existed. Netting near a maternity roost would increase the likelihood of capturing females. Similarly, some species may utilize bachelor roosts of predominantly males. It is likely that sexual segregation occurs prior to migration in *Lasionycteris noctivagans*, accounting for the preponderance of males in the sample.
While there was a wide variation in capture success by reproductive class, all pre-parturition *Myotis volans* and *M. thysanodes* were captured during the middle of June, 1997. Lactation was noted mid June through the first week in August for these species. The first sub-adults appeared after mid June for *M. volans* and mid July for *M. thysanodes*. By comparison, lactating *Eptesicus* were captured throughout the season from late May through early August. Sub-adult *Eptesicus* were first captured in early July.

Twenty bats were fitted with radio tags, representing six of the ten sensitive species captured. A total of six *Euderma* carried radio transmitters, the most of any species during the study. While each of these tags provided some valuable information about a roost location, sample sizes were only minimally adequate for *Euderma* and insufficient for meaningful interpretation for the other species tagged. Some of the radio tags were designed for larger bats that were not commonly encountered and so were not used. In addition, common species of bats were not tagged so that some radios could be saved for the more sensitive or rare species. Some bats were radio tagged and either not located again or were only found foraging. Foraging information was valuable, but did not provide any clues as to the location of roosts.

While the radio telemetry studies provided only seven roosts, 13 additional roosts were found in abandoned mines and 22 were found in caves, cracks, or crevices. A total of 42 roosts were located for 15 different species, including a number of multi-species roosts, several night roosts, one suspected maternity roost, and one suspected hibernacula.

Nearly 45 percent of the abandoned mine sites examined provided bat roosting habitat. Information about these roosts and the identity of the species using them was limited by the availability of equipment and trained personnel. Unfortunately, the scheduled inventory of abandoned mine sites on the Arizona Strip was not completed in time to be included in this study. The 28 mine sites evaluated represent less than half of the sites known or suspected on the Arizona Strip.

Approximately 15 percent of the cave sites inventoried during the course of this study provided bat habitat. Many of these sites are well known to local amateur cavers and have been repeatedly disturbed. It is not surprising that most of these features had only a few bats. Cave inventories are scheduled to minimize disturbance to roosting / hibernating bats.

The presence of vast areas of sheer cliffs on the Arizona Strip provides extensive habitat for species that roost in these areas. This includes *Corynorhinus townsendii, Euderma maculatum, Macrotus californicus, Pipistrellus hesperus, Antrozous pallidus, Eptesicus fuscus, Myotis thysanodes, M. yumanensis, M. californicus, M. ciliolabrum, Eumops perotis, Nyctinomops macrotis*, and *Tadarida brasiliensis*. Many such sites may never be located by biologists simply because many species roost singly or in small groups, prefer sites in the upper portions of cliff faces, crawl into cracks far below the surface, and switch roosts on a regular basis. However, factors that restrict human discovery and access also provide a certain measure of protection. Even sites that are close to human habitation may be relatively safe from disturbance because the sites are not developable from a human perspective.

Four *Euderma maculatum* were found in cracks or crevices at three different sites in a small canyon in the northwest portion of the Arizona Strip. Extensive searches of areas historically considered *Euderma* roosts near the Ft. Pierce ruins produced no roost sites. Poche and Baillie (1974) captured *Euderma* at this location in Southern Utah and released the animals the following day. Bats released during the day time flew less than one half mile south into large rock piles. Poche and Baillie (1974) relocated the bats and concluded they had found the roost locations. During this study we captured six male *Euderma* at the ruins on three separate occasions. These animals flew directly back down Ft. Pierce Wash into Arizona and into small side canyons approximately seven miles (11 km) from the release site. Three individual roosts were located in this side canyon and another *Euderma* roost was located on Burnt Canyon Point (T. 31 N., R. 13 W. G&SRM) in Lake Mead National Recreation Area. Site specific roost criteria were consistent between the four roost locations: all were located in cracks, crevices, or holes in the upper one third of vertical cliff faces at least 75 ft (23 m) tall. While the area around the Ft. Pierce ruins previously identified by Poche and Baile (1974) as *Euderma* roost habitat did not meet the site specific roost criteria found at the four Arizona locations, the sample size was insufficient to draw conclusions of statistical significance.

CONCLUSIONS AND RECOMMENDATIONS

While the results of mist netting opportunities presented a large volume of data for review, the number of sites netted in each habitat type examined was insufficient to draw conclusions, particularly in the desert scrub and sagebrush habitats. Study Objective 1, identifying key use areas (roosts) for bats on the Arizona Strip, was achieved. Cave and mine inventories and radio telemetry data all contributed to reaching this objective. Additional mine inventories and radio telemetry work will supplement this information in the future. Study Objective 2, identifying and characterizing tree roosts adjacent to the Mt. Trumbull Ecosystem Restoration Project, was not met. This was because the number of tree roosts located in ponderosa pine habitat was insufficient to draw any conclusions concerning the impacts of ecosystem restoration efforts. However, study results indicate *Myotis volans* is forest dwelling species that is common to abundant in the ponderosa pine forests at Mt. Trumbull. Future work should focus primarily in the Mt. Trumbull area to document the impacts to forest dwelling bats from the ecosystem restoration project and to develop the predictive model for identifying potential roost trees/snags.

Since water availability and spacing may be a factor limiting the distribution and abundance of bat species, it is important that all water sources available be maintained. This is true for wildlife catchments as well as livestock ponds, and is critical in riparian areas. Because little data is available regarding how water sources affect the distribution and abundance of bat species, more studies are needed to promote informed decision making on the Arizona Strip.

Recreational use of caves and mines on the Arizona Strip will likely increase in the future. A single human visitor to a cave or mine used as a bat maternity roost or hibernacula can be life-threatening to the colony. Permanent closure methods are generally undesirable for the same reason. The use of bat-compatible gates has been shown to be effective at a variety of bat roosts. Human safety needs can be met by installing bat gates constructed of horizontal steel bars that allow ingress and egress for bats and other wildlife. The remaining portions of the Arizona State Mine Inspector's Office abandoned mine site inventory should be completed on the Arizona Strip. Follow-up surveys should be conducted to document important roosting sites and the dependence of sensitive bat species on particular habitat types. This inventory should include documenting the location, season of use, and species present at mines throughout the Arizona Strip. With this information the appropriate decisions could be made concerning monitoring human safety issues and effective methods for mine closure.

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